SECTION 5

Conclusions

To improve the prediction of circulation in bubble columns, a theoretical and experimental effort has been undertaken at West Virginia University. The problem has been addressed using both probe studies and laser doppler velocimetry, and both one-dimensional and full numerical models have been proposed.

For the probe work a tall 8 inch diameter bubble column was constructed, and void distributions were measured with resistance probes. A distributor plate introduced air evenly over the column base. To acquire data from the probes, a new thresholding protocol was developed and verified. Data gathered at various column heights and gas flowrates showed that the void distribution was flattened near the distributor plate and became more parabolic higher in the column. Bubble velocity data proved more difficult to acquire when two probes were used, and their signals cross-correlated. Bubbles had too strong a radial velocity component to permit reliable vertical velocity measurement. Nevertheless, at the column center, some reliable bubble velocity data was obtained, and the results compared favorably with velocity calculated from the void profile witht the one-dimensional model of Clark et al. (1987).

One-dimensional modeling was also extended to incorporate a drift-flux model, and it was shown that C_o, the distribution parameter, could be obtained from the void profile. However, a priori prediction of holdup was not possible using this approach.

During the laser Doppler velocimeter (LDV) work, a series of 3-D mean and fluctuating mean and turbulent velocity measurements have been obtained in a laboratory model bubble column. These data have been acquired non-intrusively through use of a three-component LDV, for vertical air injection from a single port on the centerline at the bottom of the column. Mean velocity data confirm the existence of a strong, toroidal vortex in the top half of the column with a much weaker inwards motion in the bottom half of the column. These quantitative data are confirmed by qualitative flow visualization. Circumferential mean velocity is essentially zero. The turbulence field is non-isotropic, as expected, in that radial RMS velocities are generally larger than vertical and circumferential RMS velocities. Turbulence intensities are on the order of 100% throughout the column.

The present data contribute to the understanding of the development of liquid circulation in a bubble column. Also, data are extremely useful in the development of reliable numerical models for the turbulent multiphase flow in a bubble column. However, it would be extremely useful to obtain a similar set of velocity data for a bubble injection distributor plate which created a uniform distribution of bubbles at the bottom of the column. The present measurements could also be significantly improved through the development of LDV alignment procedures to enable simultaneous measurement of all three velocity components, so that Reynolds stresses could also be determined, as an aid in turbulence model development. While it is certain that optical penetration into the bubble column by the LDV would place limits on the magnitudes of void fraction for which such data could be obtained, still it is clear that significant improvements could be made.

Numerical calculation of the liquid circulation inside on isothermal column reactor was performed in two ways: (a) with a prescribed α-profile (shape); (b) with α-distribution calculated from teh transport equation for it.

The results indicate that the actual shape of the α-profile is not that critical with respect ot the circulation patterns and the liquid velocity. The overall magnitude of the void fraction as well as the bubble-street diameter seems to be more important.

The predictions including direct solution for α-distribution lead to a more realistic circulation pattern compared to experimental observations. The boundary condition for α at the inlet (i.e. the distributor plate) seems to play a dominant role in determining the overall circulation pattern. At this point numerical investigations need more input from experimental investigations.

The present mathematical model based on the continuum approach and the slip velocity relation seems to predict reasonable well the overall characteristics of the circulation in the bubbly flow regime. However, the full numerical solution of both the liquid and gas phases needs to be further investigated as well as the flow regimes other than the bubbly flow regime.